Habitat preferences of an endangered species in developing landscapes: the Bush Stone-curlew on the central coast of New South Wales, Australia

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ABSTRACT

The bush stone-curlew *Burhinus grallarius* is listed as 'Near threatened' on the IUCN Red List of Threatened Species. In NSW, bush stone-curlews are listed as 'Endangered' under the *Threatened Species Conservation Act 1995*. The present study focused on bush stone-curlew populations throughout the central coast of NSW and the aim of this study was to develop an inductive spatial model in Geographical Information System (GIS) of suitable bush stone-curlew habitat based on historical sightings and empirical data. To develop the models, micro-habitat data from 30 sites where bush stone-curlews have been recorded were combined with broad historical habitat maps between Gosford and Port Stephens. The habitat data and developed spatial models indicated that bush stone-curlew sightings are associated with trees dominated by *Casuarina glauca* and *Syncarpia glomulifera*. In terms of broad habitat classifications, bush stone-curlews are more likely to be sighted in wet sclerophyll forests (towards Gosford) and dry sclerophyll forests and saline wetlands (Port Stephens). The spatial model developed for this endangered bird will help direct conservation efforts to maintain and promote habitat in areas where urban development is rapidly increasing.

Key words: habitat variables, *Burhinus grallarius,* GIS, habitat preferences, shorebird, prediction model

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Introduction

Bush stone-curlews *Burhinus grallarius* are terrestrial, ground nesting birds in family Burhinidae, order Charadriiformes. They are nocturnal shorebirds becoming active from dusk to dawn (Department of Environment and Conservation 2006). Foraging occurs at night and includes areas such as irrigated paddocks, grassland, woodlands, domestic gardens, saltmarsh, mangroves and playing fields (Marchant and Higgins 1993). Their diet consists of arthropods, small vertebrates, vegetation and seeds (Marchant and Higgins 1993), though primarily insectivorous (Webster and Baker-Gabb 1994).

Bush stone-curlews are currently found in small numbers west of the Great Dividing Range and patches along the northeast and central coast of New South Wales (NSW) (Department of Environment and Conservation 2006). Bush stone-curlews are listed as '*Near Threatened*' under The International Union for Conservation of Nature Red List of Threatened Species, primarily due to predation by the introduced European red fox *Vulpes vulpes*, habitat clearance for agriculture, removal of leaf litter and overgrazing (Birdlife International 2008). In NSW, bush stone-curlews are listed as '*Endangered*' on Schedule 1 of the NSW *Threatened Species Conservation Act 1995* (Department of Environment and Conservation 2006).

Bush stone-curlews are found throughout Australia, and this includes most regions of eastern Australia, however, urbanisation in the mid 1950s initiated their decline in some areas (Larkins 1989). The close proximity of bush stone-curlews to some urban areas in NSW and their declining populations in non-rural areas have led to their subsequent conservation status. Coastal populations are under pressure from increasing coastal development compounded by high land values (Price 2004). Extensive clearing and modification of its preferred lowland woodland habitat for agriculture and urban development is a major threatening process.

The information of distribution, characteristics and spatial arrangement of preferred habitat is vital for the conservation of species (Brambilla *et al.* 2009). Tools such as basic Geographic Information Systems (GIS) applications have created new possibilities that allow the development of habitat suitability maps (Guisan and

Zimmermann 2000). Habitat models can be used to aid conservation, increase or restore critical habitats and have extensive use in conservation biology and wildlife management (Brambilla *et al.* 2009).

A better understanding of micro and macro-habitat features required for foraging, nesting and roosting is required for developing habitat management guidelines. The specific habitat requirements of bush stone-curlews remain unclear, although anecdotal evidence suggests that a mix of cleared land and remnant vegetation is sufficient to support large populations of bush stone-curlews (Gates and Paton 2005). The aims of this study were to identify the preferred habitat of bush stone-curlews throughout coastal regions of central NSW and develop a spatially explicit model using GIS to identify suitable habitat throughout the region.

Methods

Study sites

This study was conducted in what was the Hunter-Central Rivers Catchment Management Authority (HCR CMA) in NSW, now the Local Land Services of Hunter and Greater Sydney cover our study area. Within this area, Gosford Local Government Authority (LGA) and Port Stephens Local Government Authority (LGA) were the central areas for field surveys. Gosford City is located on the NSW Central Coast approximately 85 km north of Sydney. Gosford LGA has a population of 158,000 people and, with an area of 1027 km^2 is one of the largest LGAs in NSW. Local landscapes predominantly consist of steeply sloping hills and narrow valleys, and areas of flat land which tend to be separated from each other by steep ridges. Development has occurred on flat land, primarily on the Woy Woy Peninsula and in the Narara Valley.

Key industries in the region include mining, power generation, light industries, agriculture, service industries, tourism and administration (Hunter-Central Rivers Catchment Management Authority 2007). The hinterlands main land uses include forestry, horticulture, farming and rural residential development and on the coastal/estuaries residential and commercial development are dominant (Hunter-Central Rivers Catchment Management Authority 2007). A rapid population growth in the Central Coast has placed pressure on the land, water, native vegetation and wildlife. The growing population equates to an increase in land subdivision, more roads and water supply developments (Hunter-Central Rivers Catchment Management Authority 2007) subsequently reducing possible bush stone-curlew habitats (Department of Environment and Conservation 2006). Remnant natural bushland is widespread and large areas are protected within National Parks, water catchment areas, conservation areas and bushland public reserves.

Port Stephens is located approximately 200 km north of Sydney and 124 km north of Gosford on the east coast of NSW. Port Stephens LGA covers an area of approximately 979 km^2 with a population of approximately 64,000 people. The human population is expected to grow substantially over the next few decades and thus the infrastructure required to support this growth will increase pressure on natural resources and vegetation clearing (Hunter- Central Rivers Catchment Management Authority 2007). Much of the native vegetation in the Hunter-Central Rivers region has been cleared or altered for agriculture, urban development, mining, timber extraction and the introduction of weeds and pests. Since European settlement 57% of the vegetation in the region has experienced structural change, primarily on the valley floor. Consequently many woodland animals are rarely seen on the valley and are solely restricted to the slopes and rugged areas of the region (Hunter-Central Rivers Catchment Management Authority 2007).

Bush stone-curlew locations

Two hundred and ninety two bush stone-curlew sightings dating from 1952 to present were collated ('observed' sites). These sightings have been compiled by numerous organisations such as National Parks and Wildlife Services (NPWS), Port Stephens Council, Department of Environment, Climate Change and Water (DECCW), Hunter Bird Observers Club and Friends of the Bush Stone-Curlew Group, a non-profit organisation assisting in the recovery of bush stone-curlews. Of all the sightings recorded, 30 sites were chosen based on most recent sighting, reliability of sighting and accuracy of available Global Positioning System (GPS) coordinates for the compilation of habitat preferences and spatial modelling, as well as time constraints. Of the sites chosen where bush stone-curlews had been recorded, 20 sites occurred in the Gosford LGA and 10 sites in the Port Stephens LGA. Overall, a larger number of observations of bush stone-curlews were from Gosford. More observations in Gosford are likely to be due to larger numbers of observers, and likely to be due to the efforts of the Friends of the Bush Stone-Curlew Group, Gosford City Council awareness programs and recent surveys. The larger number of observations of bush stone-curlews made in Gosford was therefore reflected in the number of sites surveyed at Gosford compared to Port Stephens.

A further 30 sites with similar habitats were chosen in consultation with HCR CMA, DECCW and members of the Friends of the Bush Stone-Curlew Group. These sites were regarded as comparable to those habitats utilised by bush stone-curlews despite no bush stone-curlews being recorded at these sites previously (and despite surveys being conducted in some of these areas previously). These sites where no bush stone-curlews have been recorded were regarded as 'not observed' sites. Of the 'not observed' sites where bush stone-curlews had not been recorded, 15 sites occurred in the Gosford LGA and 15 sites in the Port Stephens LGA. However despite the 'not observed' sites never having bush stone-curlews recorded, the cryptic nature of the birds and low density in the area may mean they have just not been detected at these sites as yet. Little information is known about home ranges occupied by bush stone-curlews in NSW (Department of Environment and Conservation 2006). Distances between 'observed' and 'not observed' sites varied between 226 metres and 30 kilometres, such difference allowed for the detection of any habitat variable found to be significantly different between 'observed' and 'not observed' sites. Appendix 1 provides a list of the GPS coordinates for all 'observed' and 'not observed' sites.

Habitat surveys

Bush stone-curlews exhibit high site fidelity (Department of Environment and Conservation 2006). A 50 x 10 m belt transect was surveyed in a standard direction (northerly), for the collection of data at all 60 sites. Using a random numbers table, 10 points along the transect were chosen and parameters including herbage cover (%), rocks $<$ 20 cm in diameter (%) cover, litter (%) cover, bare ground (%), number of sticks $<$ 10 cm in diameter, main grass species and mean grass height in a 1 m^2 quadrat were measured to achieve a 100 % quadrat cover. The same random numbers were utilised as survey points along each transect. These parameters were chosen as they have previously been associated with habitat preferred by the bush stone-curlew (Marchant and Higgins 1993; Johnson and Baker-Gabb, 1994). Grasses were identified using Gibbs and Gibbs (2001) and Rose (2006). Tree diameter at breast height (DBH) of trees $\geq$ 10 cm were measured and their species recorded based on Popescu and Wynne (2004). Canopy cover percentage was measured every 5 m along the transect based on the method of Korhonen *et al.* (2006).

Spatial models in Geographical Information Systems

Habitat models created using generalised linear modelling methods can assist in identifying habitat preferences of species (Brambilla et al. 2009). If habitat variables are available as GIS layers, habitat models can be extrapolated to create maps showing preferred habitat by a given species (Guisan and Zimmermann 2000). In the present study a deductive model was first developed in ESRI® ArcGIS 9 (USA) whereby habitat data from habitat assessment surveys, geology, Vegetation/ GreatLakesLGA, Vegetation/ LH&CC_NPWS2000, Vegetation/ LNE_CRAFTI, Vegetation/LowerNorthCoastAPI_ LHCCREMS2009 and floodplain provided by Hunter-Central Rivers Catchment Management Authority were compiled in ArcGIS and used to estimate the extent of suitable bush stone-curlew habitat. The deductive model was the basis for sampling for bush stone-curlews in new areas of the study region. The locations of bush stone-curlews and the associated habitat at each site were used to predict suitable bush stone-curlew habitat over the study region. For example, bush stone-curlews are closely associated with the habitats described previously (Marchant and Higgins 1993; Johnson and Baker-Gabb, 1994; Price 2004) and these were used in the development of the model. Bush stone-curlews were also associated with coastal floodplain, and therefore geology, vegetation type and floodplain area were used to better predict bush stone-curlew probability in areas of the mask without bush stone-curlew points. The use of the additional habitat layers is appealing, but it does come with a price. Cokriging, requires more parameter estimation, therefore there is the need to sacrifice parsimony of the model for (theoretically) greater predictive power.

Results

Habitat preferences

Habitat variables were similar at and between sites at Gosford and Port Stephens despite sites at Gosford having a greater abundance of bare ground, taller grasses and more trees than 'observed' sites at Port Stephens. *Casuarina* spp. were the dominant trees found in 'observed' sites at Gosford. Kikuyu *Pennisetum clandestinum* was the main grass species and common couch *Cynodon dactylon* was also commonly found throughout all sites surveyed at Gosford. *Casuarina* and *melaleuca* were the most abundant trees recorded at 'observed' sites at Port Stephens. Buffalo *Stenotaphrum secundatum* and *C. dactylon* were the main grass species found in 'observed' sites at Port Stephens.

Geographical Information Systems model

The spatial model indicated that bush stone-curlews in Gosford tend to cluster predominantly around urbanised areas (Figure 1). In the northern areas of the CMA the model indicated high probabilities of locating bush stone-curlews, particularly in the Wyong Shire. Between Gosford and Port Stephens there are areas predicted to have suitable habitat. These areas include regions surrounding Hexham and Kurri Kurri. At Port Stephens, areas with high probabilities of having bush stone-curlews included habitats with dry sclerophyll forests dominated by *Angophora costata* and/or saline wetlands occurring mainly on sand or sandstone. Other areas with suitable habitat were found to the north north-west of Port Stephens, these areas include Clarence Town, Booral and Stroud. For Gosford and Port Stephens sites, sand and sandstone were the most important geology types associated with bush stone-curlews. Bush stone-curlews were also associated with coastal floodplains in Gosford and Port Stephens. Additionally, bush stone-curlew sites around Port Stephens were associated with conglomerate soils.

Discussion

Bush stone-curlew numbers have declined dramatically throughout NSW and this has also occurred on the Central Coast of NSW (Robinson 1998). In areas where bush stone-curlews were located, based on the survey techniques conducted during this study, habitat preferences were similar. At Gosford bush stone-curlew 'observed' sites were primarily associated with *Casuarina* spp. and at Port Stephens, *Casuarina* spp. and broad-leaved paper bark *Melaleuca quinquenervia*. Staines (2008) likewise found bush stone-curlews around Gosford in areas dominated by *Casuarina* spp. Conversely sites within Gosford and Port Stephens were different in the abundance and composition of trees and grasses.

Ground cover preferred by bush stone-curlews was different between sites at Gosford and Port Stephens however it did not differ within sites at Gosford or within sites at Port Stephens. At Gosford bush stone-curlews were associated with *P. clandestinum* and *C. dactylon* whereas at Port Stephens bush stone-curlews were associated with *S. secundatum*.

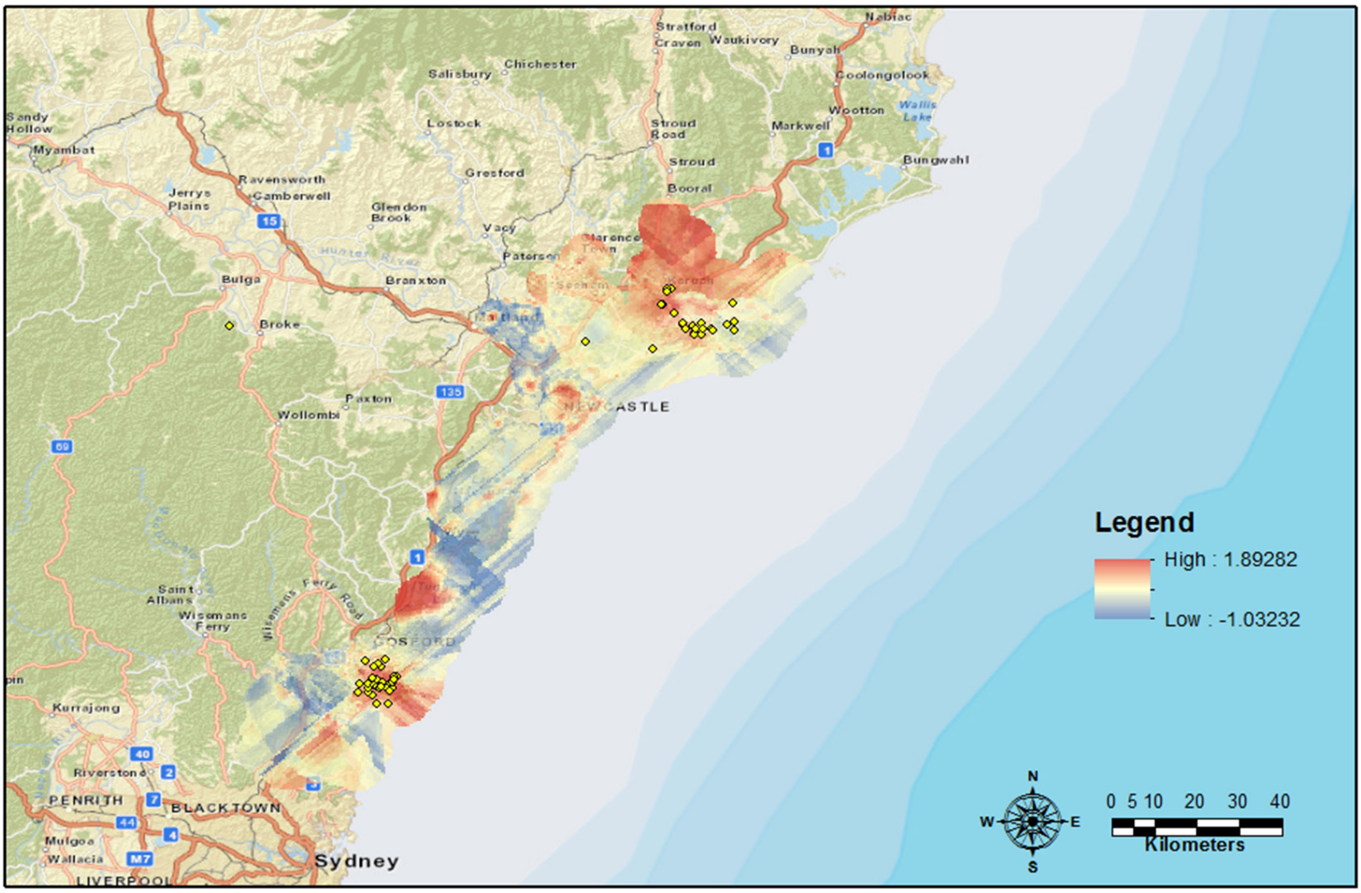

Figure 1. Map showing the confirmed location of bush stone-curlews (yellow circles) based on observed sightings. Areas predicted by the model with a high likelihood of locating bush stone-curlews (red) and low likelihood (blue) are based on cokriging values.

Although habitat variables between 'observed' and 'not observed' sites at Gosford were not different (as expected), 'observed' sites comprised a greater amount of litter, taller grasses and a greater number of trees. In Port Stephens, 'observed' sites had more herbage and greater number of trees. Having a greater number of trees in 'observed' sites signifies a larger area of shade for ground cover species to grow as it maintains ground moisture and prevents desiccation (Wong and Wilson 1980), as well as increasing leaf litter and fallen branches (Jansen and Robertson 2001). An increase in leaf litter provides a greater abundance of arthropods on which bush stone-curlews can feed (Johnson and Baker-Gabb 1994) and provide areas where they can use camouflage to avoid detection by predators (Marchant and Higgins 1993). Grassy ground cover (<15 cm) and fallen timber have been reported to be favourable habitat for bush stone-curlews previously (Marchant and Higgins 1993; Johnson and Baker-Gabb, 1994). Micro habitat variables may have contributed to differences between sites at Gosford and Port Stephens however only macro habitat variables were measured in the present study. Potential predators and competitors to the bush stone-curlew may also present a threatening process and therefore avoid sites chosen for survey. For example, a study by Banks and Bryant (2007) in Sydney showed that the abundance and diversity of woodland birds decreased if the observer was walking their dogs. Bird abundance and diversity was not affected by people walking without a dog, however birds seemed to perceive the risk of dogs in the vicinity as potential predators. As such, their study showed a 35% decrease in bird diversity and a further 41% decrease in abundance when people walked their dogs. Furthermore, 50% of ground-dwelling birds were absent from dog walking sites.

The spatial model indicated that bush stone-curlews in Gosford tend to cluster predominantly around urbanised areas (Figure 3). The model also showed that bush stone-curlews in the Gosford LGA prefer areas of wet sclerophyll forests dominated by *Casuarina glauca* and *Syncarpia glomulifera* on a substrate of sand and/or sandstone, particularly in floodplain areas. Further north there are areas with high probabilities of finding bush stone-curlews based on habitats matching Gosford, and these areas included Wyong and Toronto. Between Gosford and Port Stephens there are areas predicted to have suitable habitat. These areas include regions surrounding Hexham and Kurri Kurri. The areas predicted to be preferred by bush stone-curlews were primarily comprised of dry sclerophyll forests where sand is the main substrate. The spatial model at Gosford shows that bush stone-curlews prefer areas in close proximity to water which may provide food and water as well as provide safety from possible terrestrial predators.

At Port Stephens, areas with high probabilities of having bush stone-curlews included habitats with dry sclerophyll forests dominated by *Angophora costata* and/or saline wetlands occurring mainly on sand or sandstone. Other areas with suitable habitat were found to the north north-west of Port Stephens, these areas include Clarence Town, Booral and Stroud.

The human population on the central coast is expected to continue to increase by up to 5 000 people per year between 2006 and 2031 and urban development is expected to continue especially along the coastal fringe (Hunter-Central Rivers Catchment Management Authority 2007). One of the primary reasons for this population growth includes being situated on the Sydney-Newcastle transport corridor, subsequently experiencing increasing landuse, from rural pursuits and retirement villages to intensive urban development, industry and small holdings (Hunter-Central Rivers Catchment Management Authority 2007). The NSW government aims to focus development on the eastern side of the F3 freeway and prevent urbanisation of the western side as part of the Central Coast Regional Strategy such as the Warnervale Town Centre and Wyong Employment Zone (NSW Government n.d.). Part of this strategy is also aimed at preserving existing agricultural areas and the natural resources and environment on the western side of the F3 freeway (NSW Government n.d.). In areas of Port Stephens and to the northwest of Port Stephens including Clarence Town, Booral and Stroud, the model predicted there was suitable habitat for bush stone-curlews. Population growth in Port Stephens will further decrease the available habitat for bush stone-curlews through alteration of native vegetation (Hunter-Central Rivers Catchment Management Authority 2007). The Lower Hunter Regional Strategy and the NSW Government's Regional Conservation Plan aim to protect several important green corridors including the Wallarah Peninsula, between the Watagan Ranges and Stockton Beach, and along the Karuah River and Port Stephens foreshores.

Previous studies have incorporated the use of GIS models to predict suitable habitat despite limited species information. Brambilla *et al.* (2009) for example, used a GIS based model to determine suitable habitat for the red – backed shrike *Lanius collurio* despite the study surveying only a small region of preferred habitat to create a GIS model. The GIS based model was then extrapolated to a larger area to obtain a map of suitable habitat. Likewise Homer *et al.* (1993) used GIS models to predict suitable habitat for the declining population of sage grouse *Centrocercus urophasianus*. Given that bush stone-curlews are a cryptic nocturnal species, and not easy to locate, the model developed will aid in determining areas that are likely to be used by bush stone-curlews. In particular, it will aid future studies aimed at locating more individuals and in the longer term, aid protection of the species. A closely related family member of bush stone-curlews, the beach stone-curlew *Esacus giganteus* is also decreasing in numbers due to loss of habitat for urban and industrial development, predation, nest disturbance and nest destruction (Department of Environment Climate Change and Water 2009) and may, for example, be a suitable target.

In conclusion, this study combines citizen science with empirical data on the location and distribution of an endangered species to provide a valuable tool for land managers to identify potential habitat crucial for conserving the bush stone-curlew.

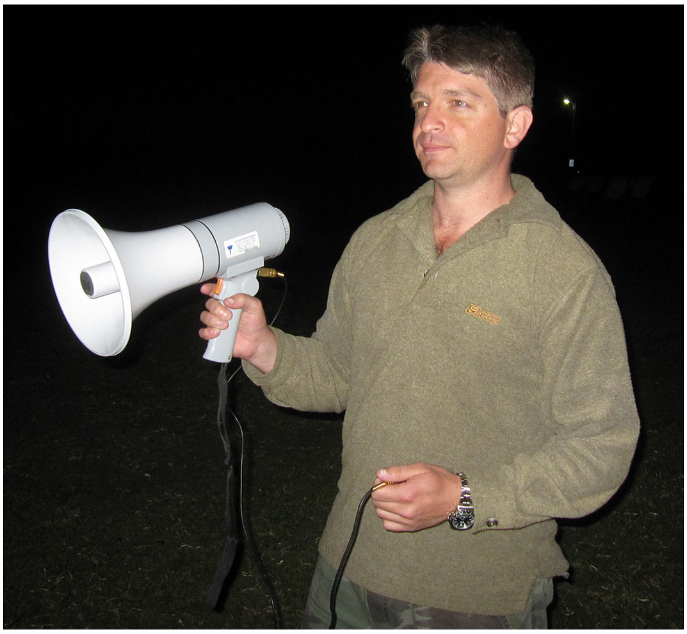

Figure 2. Researcher Gonzalo Murialdo conducting bush stone-curlew call playback surveys. Photo by Julie Old.

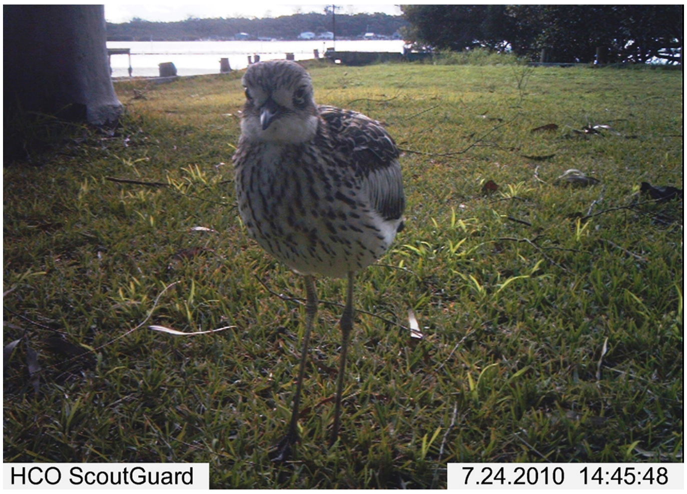

Figure 3. Infra-red camera image captured of a bush stone-curlew. Note the location is in a park near water, where the grass is short due to regular maintenance and sticks and leaf litter is limited.

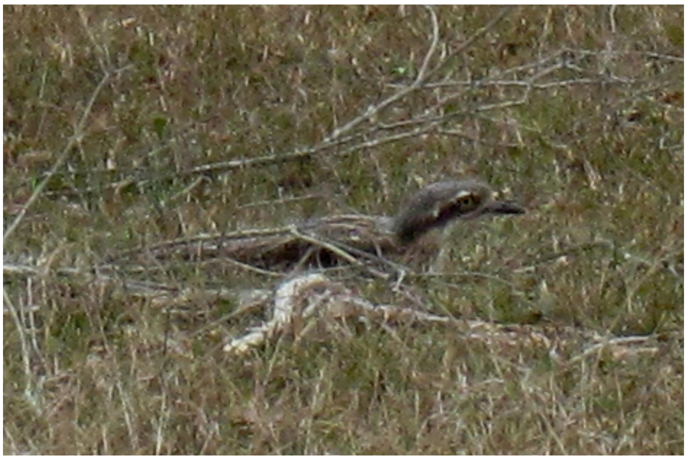

Figure 4. Photograph of bush stone-curlew resting during the day among fallen sticks. Note the bush stone-curlew is sitting on the ground among large sticks with some similar colouration, and it has its head low to the ground, presumably in an attempt to remain hidden. Photo Gonzalo Murialdo.

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APPENDIX I

Appendix 1. List of GPS coordinates for all 'observed' and 'not observed' sites for bush stone-curlews at Gosford and Port Stephens.

Site	Latitude	Longitude
Observed Site 1 Gosford	-33 29.405	151 20.558
Observed Site 2 Gosford	-33 29.572	151 20.852
Observed Site 3 Gosford	-33 30.339	151 18.512
Observed Site 4 Gosford	-33 29.068	151 21.206
Observed Site 5 Gosford	-3 29.422	151 22.215
Observed Site 6 Gosford	-33 29.699	151 21.166
Observed Site 7 Gosford	-33 28.417	151 20.306
Observed Site 8 Gosford	-33 28.426	151 20.304
Observed Site 9 Gosford	-33 28.699	151 20.915
Observed Site 10 Gosford	-33 30.043	151 22.486
Observed Site 11 Gosford	-33 29.705	151 22.810
Observed Site 12 Gosford	-33 29.692	151 22.086
Observed Site 13 Gosford	-33 28.399	151 20.333
Observed Site 14 Gosford	-33 28.246	151 22.978
Observed Site 15 Gosford	-33 28.868	151 22.879
Observed Site 16 Gosford	-33 29.006	151 22.902
Observed Site 17 Gosford	-33 28.653	151 23.137
Observed Site 18 Gosford	-33 28.939	151 21.648
Observed Site 19 Gosford	-33 30.056	151 22.520
Observed Site 20 Gosford	-33 29.505	151 21.490
Not Observed Site 1 Gosford	-33 31.646	151 22.305
Not Observed Site 2 Gosford	-33 31.646	151 20.810
Not Observed Site 3 Gosford	-33 30.560	151 20.250
Not Observed Site 4 Gosford	-33 30.228	151 19.772
Not Observed Site 5 Gosford	-33 28.422	151 23.219
Not Observed Site 6 Gosford	-33 28.256	151 23.503
Not Observed Site 7 Gosford	-33 29.047	151 21.581
Not Observed Site 8 Gosford	-33 27.078	151 21.442
Not Observed Site 9 Gosford	-33 26.133	151 21.901
Not Observed Site 10 Gosford	-33 26.566	151 21.068
Not Observed Site 11 Gosford	-33 26.931	151 20.510
Not Observed Site 12 Gosford	-33 26.215	151 19.491
Not Observed Site 13 Gosford	-33 29.638	151 19.859
Not Observed Site 14 Gosford	-33 29.107	151 19.869
Not Observed Site 15 Gosford	-33 29.171	151 18.632
Observed Site 1 Port Stephens	-32 43.949	152 02.172
Observed Site 2 Port Stephens	-32 39.092	151 58.266

APPENDIX I

Observed Site 3 Port Stephens	-32 41.138	151 57.124
Observed Site 4 Port Stephens	-32 41.133	151 57.021
Observed Site 5 Port Stephens	-32 42.218	151 58.648
Observed Site 6 Port Stephens	-32 41.009	152 05.994
Observed Site 7 Port Stephens	-32 44.836	152 01.173
Observed Site 8 Port Stephens	-32 44.870	152 01.196
Observed Site 9 Port Stephens	-32 44.965	152 02.100
Observed Site 10 Port Stephens	-32 43.851	152 00.999
Not Observed Site 1 Port Stephens	-32 44.257	152 03.343
Not Observed Site 2 Port Stephens	-32 43.630	151 59.757
Not Observed Site 3 Port Stephens	-32 43.545	151 59.662
Not Observed Site 4 Port Stephens	-32 44.242	152 01.306
Not Observed Site 5 Port Stephens	-32 46.734	151 55.789
Not Observed Site 6 Port Stephens	-32 45.807	151 47.264
Not Observed Site 7 Port Stephens	-32 39.137	151 57.606
Not Observed Site 8 Port Stephens	-32 39.427	151 57.763
Not Observed Site 9 Port Stephens	-32 43.534	152 02.015
Not Observed Site 10 Port Stephens	-32 44.270	152 02.212
Not Observed Site 11 Port Stephens	-32 44.356	152 03.400
Not Observed Site 12 Port Stephens	-32 44.378	152 06.187
Not Observed Site 13 Port Stephens	-32 44.228	152 00.046
Not Observed Site 14 Port Stephens	-32 43.640	152 05.244
Not Observed Site 15 Port Stephens	-32 43.374	152 06.276